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REPORT No. IX.

The Protection of Steel from Corrosion.

BOSTON, MASSACHUSETTS, U. S. A.

DECEMBER, 1903.

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THE PROTECTION OF STEEL FROM CORROSION.

INTRODUCTION.

In our first report upon the corrosion of steel, No. IV., the results given of tests to that date were more of a negative than of a positive character, indicating the causes of danger more than the methods of prevention. Subsequent experiments and investigations have developed methods of prevention, as yet limited, but effective in many of the most dangerous points where corrosion may occur; notably in the footings of steel-framed buildings when of necessity placed in damp ground. It may be suggested that however remote may be the causes of hazard in the superstructure, steel embedded in or adjacent to damp ground in the neighborhood of the currents of electricity of the trolley tracks, must be protected not only from the ordinary dangers of corrosion, but from the electrolysis, which is so destructive in respect to thick cast-iron water pipes. Professor Norton's report will also suggest other positive elements in the case, while disclosing the causes of hazard yet more fully than in our previous report.

Whether or not the steel footings or supports of high buildings, when embedded in damp ground, may be corroded by electrolysis from leaking currents from an electric trolley track, is surely a problem which requires immediate solution. If there is such a danger it may perhaps be met in existing buildings by encasing the footings of such buildings in an asphalt concrete, absolutely impervious to moisture. Dry steel may carry electric currents without injury. The electrolysis or dissociation of the steel occurs when the current leaves the metal, passing into damp ground or other wet substances. Possibly a remedy, if this evil exists, may be found by attaching a conducting wire to the steel footing and thus carrying the electricity derived from the trolley track to some other point. Of course such currents should be cut off if possible lest they cause danger in steel-framed buildings above the footings or supports.

PAINTS.

The subject of paints will now be taken up for thorough investigation, apparatus having been invented and methods of testing devised, which are submitted in this report. From the best information that I have been able to gather on this matter, it would appear that any paint on which reliance can be placed for the protection of steel or other metal from corrosion must be one which dries by evaporation or sets like hydraulic lime: *it must not be one which hardens by the oxidation of the oil or any other ingredient of the compound in which lead or other pigments are mixed.* Steel, having great affinity for oxygen, is corroded by the oxidation of the oil itself, while the outer surface of the paint, exposed to the air, may stop moisture from penetrating for a very considerable period of time, or until the oxidation of the body of the oil has released the lead or other pigments, thus exposing the steel surface to a humid atmosphere by the complete destruction of the paint.

Steel may be protected by paints, cements or coverings that have more affinity for oxygen than steel itself. Such coverings will absorb from the atmosphere, even when humid or loaded with particles of oxidizable matter, all that would tend to corrode before it reaches the steel.

It is in that direction that efforts have been made, and are now being made, for making paints or thin veneers for the covering of steel that will neither corrode it by their own contact or permit corrosive elements to reach the steel. Such paints or veneers must not be brittle. They must be sufficiently elastic to yield to the contraction and expansion of the steel without cracking or chipping. We have information of one such paint, made for many years in England by a secret process, which has been used upon the British ships for a long period and now being made in this country. Under these conditions the investigations which we now propose to undertake seem to the undersigned to be of the gravest importance.

Respectfully submitted,

EDWARD ATKINSON,
Director.

BOSTON, MASS., U. S. A.
December 26, 1903.

THE PROTECTION OF STEEL FROM RUST.

Since the publication of report No. IV., in which was given an account of some laboratory experiments which showed the great degree of protection afforded structural steel by Portland cement concretes, the experiments have been carried on continuously.

RESULTS.

All the early tests which were carried out on perfectly clean steel have now been repeated on specimens in all degrees of initial corrosion, with the same results as shown in the case of the chemically clean steel. Doubt existed in the minds of some engineers as to whether the results as found with clean steel would apply to rusty or dirty steel. The method adopted in the early test was to imbed the specimens in blocks of concrete about 3" x 3" x 8", allow them to set under ordinary conditions and then expose them to changing conditions of warmth, moisture, and to carbon dioxide, with traces of sulphurous gases and ammonia. Under these conditions unprotected steel vanished into a streak of rust, but protected by an inch or more of sound Portland cement concrete the clean steel was absolutely unchanged. We can now state further, that this same protection is afforded any ordinary structural steel of that degree of cleanliness likely to be found in use for building.

SPECIMENS.

The origin of many of the specimens was rather obscure, as the more corroded ones were taken from scrap heaps of steel works, many having been exposed to the weather for several years. Some had been in buildings as part of the structure, some in salt water, some in fresh water, some in damp ground, and the rest exposed to air under various conditions of dampness. The degree of rust on the specimens varied greatly, from a light yellowish stain to a scale more than one-eighth inch in thickness.

PROCEDURE.

The specimens were first cut to a size such that their length was not far from three inches and their width about one inch. They were of all thicknesses from $\frac{1}{50}$" to 1¼". Some were cut dry, some in water, some with the mill fed with oil, and a part of these cut with oil were cleaned with gasoline, and a part with alkaline solutions, while a third part were left more or less oily. It was intended that the specimens should include everything met with in regular practice.

Each specimen was stamped and the blows of the steel stamp were sufficient to loosen any rust or scale that was not firmly attached, and a vigorous brushing with a soft wire brush removed any loose dust. Each piece was next weighed, and then calipered at several points, and incorporated in a block, or brick, of concrete, sufficiently large to cover it everywhere to a depth of one inch and one-half. The mixture was one part cement, two and one-half parts sand, and five parts broken stone in some cases, and one part cement, three parts sand, and six parts cinders in others. The cements used were Alpha, Lehigh, and Alsen, and care was taken in selecting the sand and stone. The latter was of such size as to pass a one-inch mesh. The concretes were allowed to set twenty-four hours in air and seven days in water, and were

then divided into three groups, one being set out-of-doors, one stored in a damp and odorous basement underground, and the third being treated in the "corroders" or steam and carbon dioxide tanks. These galvanized iron tanks were supplied intermittently with steam, hot water, moist air, dry air, and quite continuously with carbon dioxide for periods of from one to three months. There were a number of specimens which were further exposed in tide water, in sewers, over furnaces, with constant contact of furnace gases.

CONDITION OF SPECIMENS.

After varying lapses of time from one to three months for the specimens in the "corroders," and from one to nine for the others, the specimens were broken out of the briquettes, cleaned by brushing, and weighed and calipered. Not one specimen had shown any sensible change in weight or dimension, except where the concrete had been poorly applied. Some specimens were purposely bedded in very dry concrete, and some in concrete partly set, and many of these were not well covered and the steel was seriously attacked where there were voids or cracks. Of the hundreds of specimens of rusty steel examined not one which had a continuous, unbroken coating of concrete, gained or lost anything in volume or weight by treatment which caused the practical destruction of some of the unprotected specimens. If loss by corrosion as great as $\frac{1}{1000}$ of the loss occurring with the unprotected specimens had been experienced in the case of the protected pieces it would have readily been noted.

CONCLUSIONS.

It would therefore seem that if we admit that from a severe trial of a short duration, we may judge relatively of the effects of the less severe but longer test of time, it can not be questioned that structural steel is safe from corrosion if incased in a sound sheet of good concrete, at least for a period of years so long as to make the subject of more interest to our great-grandchildren's children than to us. We know that bare steel does not rust and fall down over night, and that much of the steel standing has been bare of everything that could protect it, for long years, and it seems to me beyond question that steel properly covered in concrete may well be expected to last far longer than the changes in our cities will allow any building to remain.

There is one limitation to the whole question, that is the possibility of getting the steel properly incased in concrete. Many engineers will have nothing to do with concrete because of the difficulty in getting "sound" work. This is especially true of cinder concrete, where the porous nature of the cinders has led to much dry concrete and many voids, and much corrosion. I feel that nothing in this whole subject has been more misunderstood than the action of cinder-concrete. We usually hear that it contains much sulphur and this causes corrosion. Sulphur might, if present, were it not for the presence of the strongly alkaline cement; but with that present the corrosion of steel by the sulphur of cinders in a sound Portland concrete is the veriest myth, and as a matter of fact the ordinary cinders, classed as steam cinders, contain only a very small amount of sulphur. There can be no question that cinder-concrete has rusted great quantities of steel, but not because of its sulphur, but because it was mixed too dry, through the action of the cinders in absorbing moisture, and that it contained, therefore, voids; and secondly, because in addition the cinders often contain oxide of iron which, when not coated over with the cement by thorough wet mixing, causes the rusting of any steel which it touches.

There is one cure and only one, mix wet and mix well. With this precaution I would trust cinder-concrete quite as quickly as stone concrete in the matter of corrosion. It has been

suggested that steel which has been rusted to a slight depth becomes protected by this coating from further rusting. Nothing could be further from the truth. A large number of specimens were rusted by repeated alternate wetting and drying to see if they finally reached a constant condition. Instead of doing this, they all showed an irregular but persistent loss in weight, on further rusting, until some had practically been washed away.

The increasing use of steel of small dimension in floors and roofs, twisted rods, expanded metal, etc., has caused some question as to the advisability of their use in view of the possible great effects of corrosion, as compared with the effects of corrosion on larger members, but with sound concrete of a thickness of about one and a half inches between the steel and the weather I do not question the durability of these lighter members.

The destruction caused to steelwork by rust is certainly not more appalling in most instances, at least, than that caused by electrolysis. The action here is more apt to be local, and hence more dangerous in that inspection or protection of other parts of a structure will not indicate or prevent impending disaster to the one member which may serve as the point of departure of the escaping electric current. No satisfactory treatment other than some sort of waterproofing has appeared to be successful, and study of this matter is going on at present in many places. It is a problem for the chemist rather than for the engineer.

The next step in this research is to find out in the same general way the degree of protection afforded by paint, and second, by brick and tile work. This is now under way and the rapidity with which the "corroders" destroy some paints is such that a report on this subject may be looked for in the near future.

The investigation of the relative efficiency of different paints as a protective coating for structural steel being now under way, it is desired that all kinds of paint be submitted to our test of exposure to varying conditions. To this end we invite all dealers and manufacturers of paint, for this purpose, to send samples to the amount of one gallon to Professor C. L. Norton, Room A, Walker Building, Massachusetts Institute of Technology, with any directions for applying the paints to either clean or ordinarily rusty steel. The results of these tests will not be published without the consent of the persons submitting the paint to test.

Some pieces of steel will, after coating with the paint under test, be submitted to various corrosive influences, and the details of the exposure being such as will correspond in nature to the actual exposure of structural steel, but of an intensified degree, it is believed that relative results may be arrived at in a reasonably short time in this way.

Respectfully submitted,

CHARLES L. NORTON.

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